

Studies of the static magnetic microstructure in functional multilayered thin film systems

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INTRODUCTION

The magnetism of systems with reduced dimensionality, as e.g. magnetic thin layers, multilayered films and laterally nanopatterned elements are subject to intensive experimental and theoretical studies. Magnetic thin film systems serving as key materials in current magnetic storage and sensor technologies are being composed of a large variety of elements to design distinct functionalities. Since these are deeply related with the magnetic microstructure, a layer resolving imaging of magnetic domains on a nanometer scale is an outstanding challenge. Magnetic soft X-ray transmission microscopy (MTXM), combining high lateral resolution given by Fresnel zone plate optics with X-ray magnetic circular dichroism as magnetic contrast, is a powerful technique for such studies [1-4]. Inherent element specificity and the applicability of external magnetic fields during the recording allow addressing the magnetic properties of individual layers in multilayered systems. Currently, the full-field MTXM at the Advanced Light Source in Berkeley CA, where the presented data have been taken, has a lateral resolution down to 25 nm and covers the X-ray energy range between 250-1800eV thereby giving particular access to the L edges of 3d transition metals (e.g. Fe, Co, Ni) and the M edges of 4f systems (e.g. Gd, Tb), where huge magnetic contributions to the photoabsorption cross sections up to 25% occur. Since the projection of the magnetization onto the photon propagation direction gives the magnetic contrast, both out-of-plane and in-plane magnetized domains can be imaged by tilting the samples surface with respect to the photon beam direction.

RESULTS

- Nanopatterned exchange bias elements

Due to the competition of stray field, exchange and anisotropy energies, the multidomain state is more favorable for specimens with dimensions larger than characteristic exchange lengths, while small particles form a single domain state to achieve the magnetic ground state. The question of which specific configuration is formed and in particular the investigation of their characteristic switching behavior is of utmost interest. An important class of magnetic materials are coupled antiferromagnet/ferromagnet systems, because they exhibit an exchange bias effect for which the microscopic origin is not yet fully understood. Fig. 1 displays the MTXM results obtained at the Fe L₃ edge (706eV) of an array of squared nanopatterned elements of a 20nm MnIr/10nm PY layered system. Four-domain Landau configurations are visible for all sizes, however, with different senses of rotation. This might be due to local inhomogeneities which result in different local starting configuration for each element. Since the nominal thickness of Fe in PY is only about 2nm, these results demonstrate the high sensitivity of MTXM. It has to be mentioned that a ferromagnetic component in the AF layer similar to recent X-PEEM measurements [5] could not be detected. The observed domain structure is consistent with magnetic force microscopy (MFM) results, however, the MTXM images in Fig. 1 show the local Fe magnetization directly rather than the stray fields, which the MFM technique is probing.

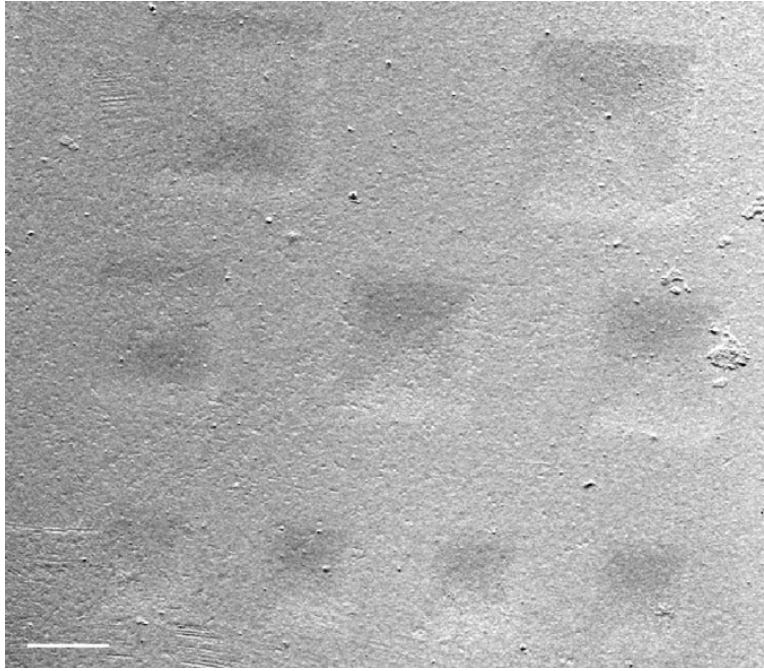


Figure 1. Static domain pattern in squared [20nm MnIr/10nm PY ($\text{Ni}_{80}\text{Fe}_{20}$)] elements recorded at the Fe L_3 edge (706eV). The bar corresponds to 1 μm .

- MAMMOS systems

Increasing the storage density in magneto-optics has two key issues. Recording focuses on small laser beam spots achieved with a high numerical aperture (NA) lens, the use of shorter wavelength with a blue laser and a recording scheme with laser pumped magnetic field modulation (LP-MFM) where chevron shaped stable domains can be written. The magnetic amplifying magneto-optical system (MAMMOS) was proposed as readout scheme [6]. The bits are written into a TbFeCo recording layer and read out from a GdFeCo layer. Due to different coercive fields and Curie temperatures of both layers, a small written bit is copied into the readout layer. By applying an external magnetic field the copied bit is expanded into a larger domain, which can be easily detected by the laser system. The copying process and the formation of magnetic domains in each individual layer can be tackled by MTXM due to the element-selectivity and the possibility to record images within external magnetic fields. Results obtained with a MAMMOS system ([30nm Al alloy / 20nm SiN / 40nm TbFeCo (recording layer) / 9nm SiN / 30nm GdFeCo (readout layer) / 60nm SiN 60nm] are shown in Fig. 2. The domain structure of the (magnetically hard) TbFeCo layer is not influenced by applying a weak magnetic field, which however is sufficient to saturate the magnetically soft readout layer. In the left panel of Fig. 2 the total signal at a field of 180 Oe is shown. The domain structure in the readout layer, which can be obtained by normalizing the images recorded within the magnetization switching cycle to the image at saturation is shown in the right panel. Besides studying the elemental composition of MAMMOS systems, investigations of the thermodynamic character of the writing/reading processes by varying the temperature during image recording will be feasible in the future.

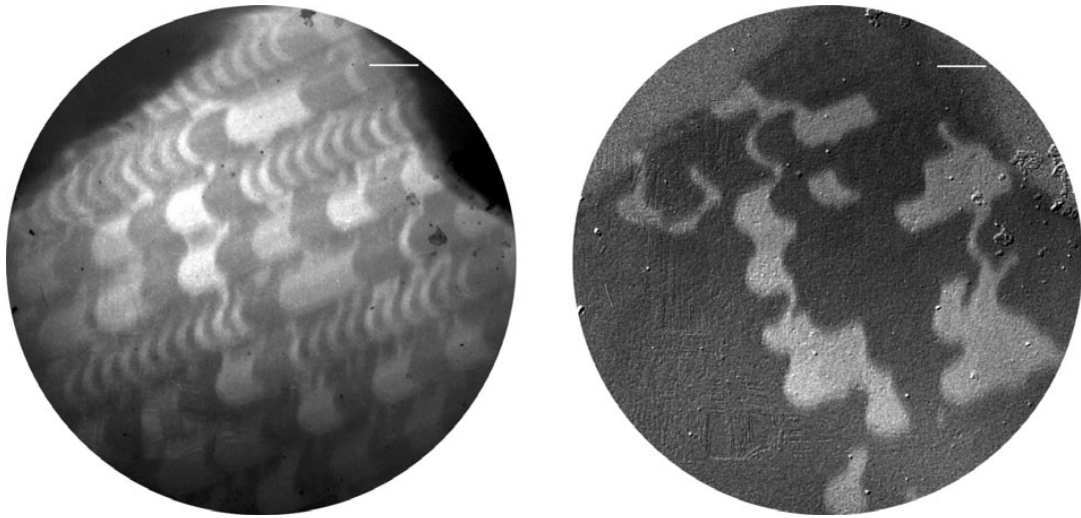


Figure 2. Chevron-like written bit pattern in a MAMMOS system imaged at the Fe L_3 edge in an external field of 180 Oe. Left: Total signal of read-out and recording layer. Right: Read-out layer signal normalized to a saturated read-out image. The bar corresponds to 1 μm .

OUTLOOK

The complementarity of MTXM with X-PEEM measurements will be stressed by further studies of nanopatterned EB systems to elucidate the origin of EB and its dependence on geometry and surface/interface properties.

The recent successful demonstration of studying spin dynamics in the sub-ns time regime makes it feasible to study the temporal evolution of the reading/writing process in MAMMOS systems.

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